

A Prototype Quasi-Optical SIS Array Receiver

Philip A. Stimson, Robert J. Dengler, Henry G. LeDuc and Peter H. Siegel

Jet Propulsion Laboratory, Pasadena, CA, 91109

Abstract—We report measurements on a prototype SIS array receiver consisting of a ten-element dipole antenna array with half square micron niobium SIS junctions. The mixer array is a completely planar, integrated device mounted on the front surface of a quartz-filled parabolic reflector. The ten mixer elements are switched into a single IF filter-amplifier chain. Results at 230 GHz show receiver noise temperatures as low as 75 K DSB, with 120 K being a typical value.

I. INTRODUCTION

Planar quasiparticle superconductor-insulator-superconductor (SIS) receivers have been used for some years, and have recently demonstrated performance comparable with the best waveguide systems [1] [2]. The advantages of a waveguide receiver include backshort tuning to reduce the effect of parasitic reactance and excellent antenna patterns due to the waveguide horn. Planar systems using substrate lenses on the other hand, are fixed-tuned (but see reference [3]) and the antenna patterns are very system dependent, almost always suffering from some reflection loss at the lens-air interface and back radiation from the antenna into the air. Advantages include ease of fabrication and assembly at high frequencies, and importantly, the possibility of realizing compact, light-weight arrays. This may be achieved by fabricating many mixer elements and SIS junctions on a wafer placed at the rear of a lens, and using planar transmission line feeds. The size and weight of the receiver front end is then no greater than that for the corresponding single element device. An alternative approach is to fabricate an assembly of individual quasi-optical mixers, which are tiled together in the image plane [4] [5] [6].

11. QUASI-OPTICAL ARRAY RECEIVER

The array receiver used here is a totally planar, monolithic device. The junction-antenna wafer carries a 2x5 array of resonant dipole antennas with $0.7 \times 0.7 \mu\text{m}$ niobium-aluminum oxide-niobium SIS junctions at the terminals. No tuning is used for the SIS junctions. The antennas are spaced 0.53 and $0.35 \lambda_e$ (the effective wavelength) apart in the E- and H-planes respectively.

The junctions were fabricated using E-beam lithography and a self aligned lift-off trilayer process [7]. The mixer block, shown in Fig. 1, consists of the wafer, a quartz reflector, and IF baluns and connectors mounted in a brass housing. The wafer is held on the flat face of a quartz parabolic lens, whose rear surface is metalized. Incoming radiation is reflected by the metal surface and focussed onto the antenna elements at the center of the wafer. The configuration, called a Dielectric-Filled Parabola (DFP), is analogous to a conventional parabolic dish antenna. The IF signals are coupled from the wafer via coplanar strip transmission lines. Monolithic IF baluns transform the 200Ω characteristic impedance of the coplanar strips to that of 50 Ω coaxial transmission line. The ten mixer elements are switched electronically into a single low-noise IF system which is designed to permit accurate determination of the mixer and receiver noise temperatures and conversion loss. This does not permit simultaneous measurement of the individual elements. For a prototype receiver, the considerable expense of ten IF channels is not justified. Details of the design, scale modeling, junction fabrication, and RF measurement techniques have been published previously [8] [9].

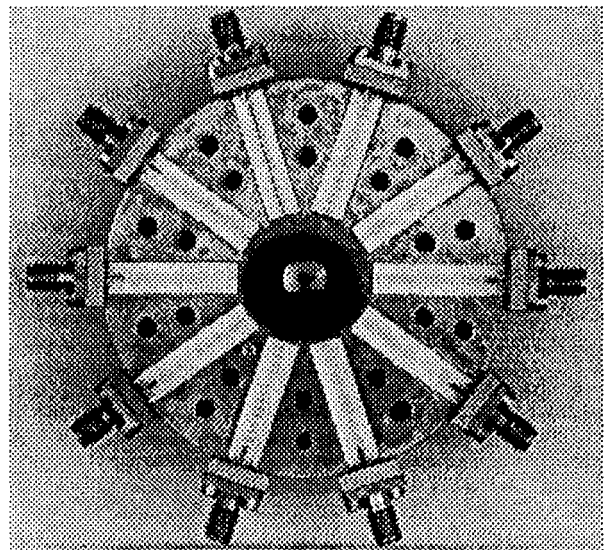


Fig. 1. The mixer block with the upper half removed. The central dielectric-filled parabola (dark), containing the antenna and mixer elements, is surrounded by 10 IF baluns (light) and SSMA connectors at the edge of the block.

111. RESULTS AT 230 GHz

Typical I-V curves for the ten SIS junctions are shown in Fig. 2. Two of the curves exhibit high sub-gap leakage. Our first experiment established the performance of each mixer element at its optimum local oscillator power. Four of the ten elements gave DSB mixer noise temperatures of about 90 K at band center. The remaining elements gave mixer noise temperatures between 100 K and 200 K. The optimum LO power level for the best and the worst elements differed by only 2 dB.

Next, we examined the variation of mixer noise temperature with LO power. The array receiver is pumped by a single LO source injected via a rear hole in the reflector metallization, so LO power cannot be optimized for each element individually in the operating mode. Noise temperature and conversion loss are comparatively mild functions of the LO power near the optimum value as shown in Fig. 3. We determined a globally optimized LO power which produced mixer noise temperatures only 10 K and 30 K higher, for the better and poorer elements respectively, than the individually optimized levels. At an IF frequency of 1.35 GHz, the mixer noise temperature of all ten elements was then between 95 K and 235 K as shown in Fig. 4. The receiver noise temperatures of the ten elements were between 150 K and 400 K DSB. The IF system noise temperature was approximately 7 K. The conversion loss of the mixer elements was measured to be approximately 8 dB into a matched load.

The best performance so far recorded from this receiver is shown in Fig. 5. These data were recorded from a single mixer on a wafer which did not have all ten SIS junctions operating. The receiver noise temperature (DSB) is shown as a function of LO frequency. Values down to 75 K DSB were obtained. The better receiver

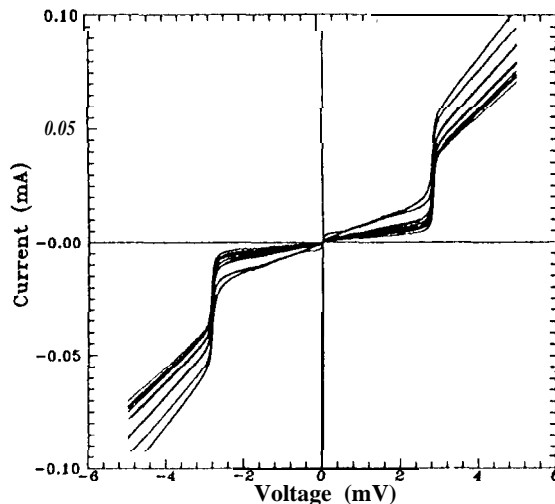


Fig. 2. DC I-V curves of the ten SIS mixers in the array. Two of the curves display high subgap leakage.

performance is due both to improved mixer noise temperature, and improved IF system performance (5 K). The conversion loss was the same as the previous measurements. Similar untuned junctions have produced receiver noise temperatures of 50 K DSB in a waveguide mixer at 345 GHz [10].

IV. DISCUSSION

Element performance is not significantly effected by LO power variations across the array. The aperture of the LO injection horn is $1.4\lambda_D$ which produces a 3 dB beamwidth of approximately 30° in the quartz. The edge element subtends an angle of 6° from boresight. Individual elements are relatively insensitive to LO variation around the optimum value (Fig. 3), and the small difference in the power delivered to the edge element compared to that delivered to the center element produces only a minor performance reduction.

Far more significant is the variation in performance due to individual junction quality as evidenced by the sub-gap leakage variation in Fig. 2. This problem is soluble in the sense that as fabrication technology advances, junctions of any given performance specification can be produced more repeatably. Junction uniformity will continue to be a problem in fully integrated arrays however, when working at the limit of available fabrication processes. Improvement in the uniformity from that demonstrated here would be required to make an array receiver a viable replacement for a single element device. The junctions used for this work were untuned. If tuning stubs or multiple SIS junctions were used, larger area devices may produce equivalent results and offer greater uniformity.

The noise temperature variations in Fig. 5 are believed to arise from multiple reflections in the quartz

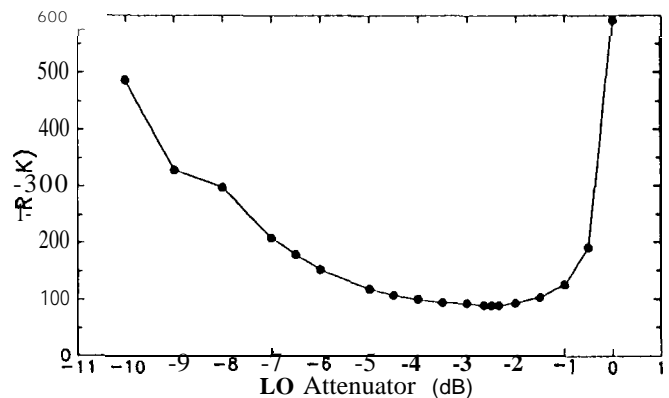


Fig. 3. Receiver noise temperature (DSB) as a function of LO Power. The ordinate is the setting on a variable attenuator. Power increases to the right.

parabola. Their period corresponds to the parabola thickness. A Teflon antireflection coating is used on the quartz front face in an attempt to suppress reflections, but apparently, it is not performing as expected. No measurements were possible in the region from 200-215 GHz due to oscillations in the mixer IF power.

We are currently testing a 492 GHz version of the array receiver which incorporates a tuning stub on each junction.

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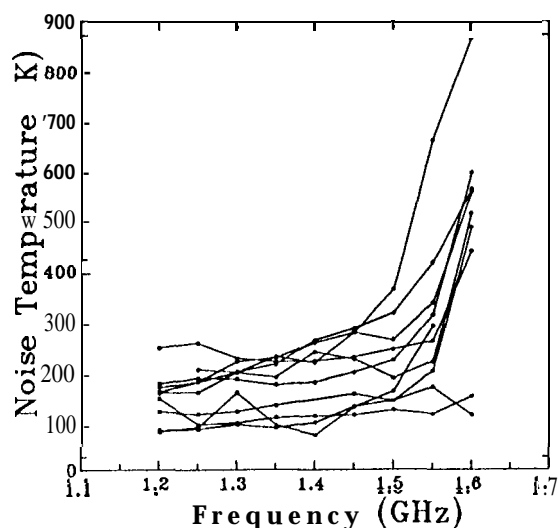


Fig. 4. Receiver noise temperature (DSB) as a function of IF frequency for the ten array elements. A fixed LO power was used for all elements.

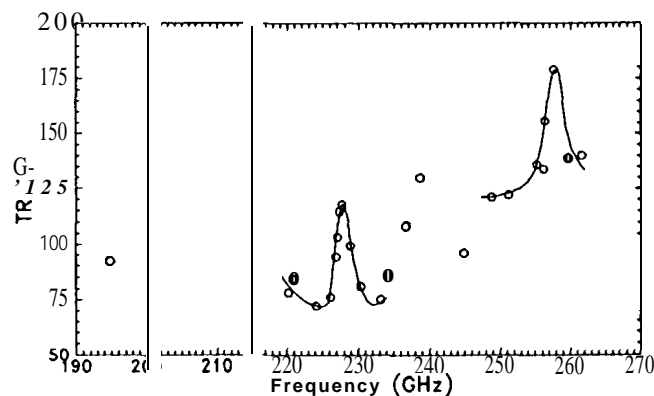


Fig. 5. Receiver noise temperature (DSB) as a function of LO frequency for the best mixer element tested so far. Noise temperatures down to 75 K are observed. The peaked feature of the curve is due to multiple reflections within the parabola.